MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 1, 2018/2019

EEE1016 – ELECTRONICS 1

(All Sections / Groups)

24TH OCTOBER 2018
9:00 am – 11:00 am
(2 Hours)

INSTRUCTION TO STUDENTS

1. This Question paper consists of **9 pages,** including cover page and appendix, with **4 Questions** only.

2. Attempt **ALL** the questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the answer Booklet provided.

QUESTION 1

(a) The atomic number Z gives the number of electrons in an electrically balanced atom. Table Q1(a) presents a list of elements and their atomic numbers.

(i) Identify **TWO** elements which can be used to form an N-type semiconductor material. State their electron configurations. [3 marks]

(ii) Based on your answer in Part (a)(i), sketch the covalent bonding diagram. Next, explain how the majority carriers are produced in the N-type material. [5 marks]

Table Q1(a)

Element	Atomic number, Z
A	13
B	15
C	32
D	36

(b) For a sample of intrinsic Germanium (Ge), the electron and hole mobilities are found to be $\mu_n = 3900$ cm^2/V-s and $\mu_p = 1900$ cm^2/V-s, respectively. A drift current density of 2.5 A/cm^2 is established in the pure Ge with an applied electric field of $E = 50$ V/cm.

(i) Find the intrinsic carrier concentration of the Ge. [3 marks]

(ii) The Ge material is doped to the extent of 1×10^{15} donor atoms/cm^3 and 8×10^{14} acceptor atoms/cm^3. Determine the electron and hole concentrations of the extrinsic Ge material. [6 marks]

(c) Figure Q1(c) depicts a diode circuit with a supply voltage, $V_S = 30$ V and resistor $R_S = 470\ \Omega$. The silicon diode D1 has a cut-in voltage, $V_\gamma = 0.7$ V and its forward diode resistance R_f is negligible. The zener diode D2 has a zener voltage $V_Z = 5.3$V. Determine the followings:

(i) The current I and the voltage V_O in the circuit. [4 marks]

(ii) The power dissipated by the zener diode D2. [2 marks]

(iii) The value of R_S that limits the current I to 150 mA. [2 marks]

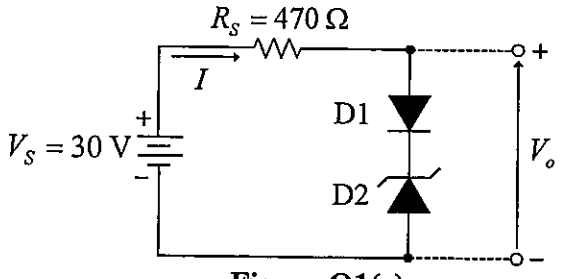

Figure Q1(c)

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QUESTION 2

(a) Figure Q2.1 and Figure Q2.2 show the full-wave Bridge rectifier circuit and the input voltage waveform, V_i, respectively.

(i) Draw the output voltage waveform of this rectifier, assuming ideal diodes with $R_f = 0$, $R_r = \infty$, and $V_\gamma = 0$. [1 mark]

(ii) Draw the output voltage waveform of this rectifier if all diodes in the circuits have cut-in voltage, $V_\gamma = 0.7$ V, $R_r = \infty$, and R_f is negligible. [2 marks]

(iii) Use circuit diagrams to explain your output voltage waveform in Part (ii) over one full-cycle ($0 \leq \omega t \leq 2\pi$). [3 marks]

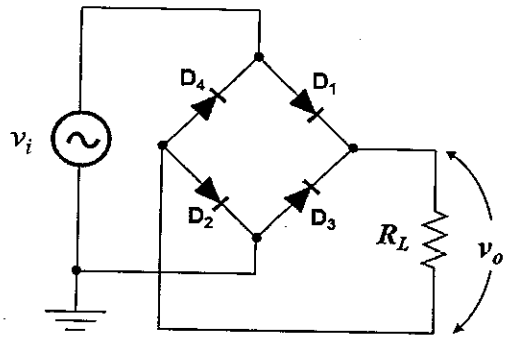

Figure Q2.1

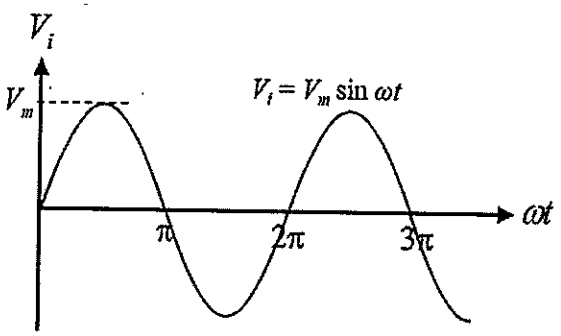

Figure Q2.2

(b) Consider the input voltage signal for the rectifier of Figure Q2.2 with $V_m = 10$ V and $f = 5$ *kHz* and the load resistor in Figure Q2.1, $R_L = 5$ kΩ. Determine:

(i) The average output voltage, $V_{o(av)}$ [2 marks]

(ii) The average load current, $I_{o(av)}$ [2 marks]

(iii) The rms load voltage, $V_{o(rms)}$ [2 marks]

(iv) The rms load current, $I_{o(rms)}$ [2 marks]

(v) The average power through R_L, P_{dc} [2 marks]

(vi) The average power absorbed by R_L, P_{rms} [2 marks]

(vii) The efficiency, η [2 marks]

Continued ...

(c) Use silicon diodes with cut-in voltage V_γ = 0.7 V to design a clipper circuit to produce the output voltage waveform, V_o, as shown in Figure 2.3. The dash line represents the input voltage waveform, $V_S = V_m \sin(\omega t)$. Draw the clipper circuit and explain your circuit diagram. [5 marks]

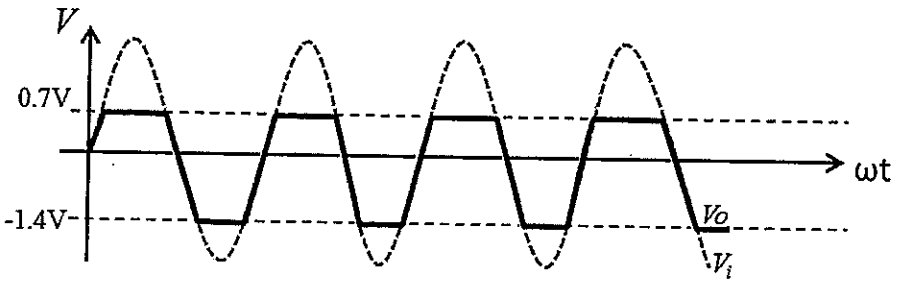

Figure Q2.3

QUESTION 3

(a) Figure Q3(a) is a representation of the physical structure of NPN Bipolar Junction Transistor (BJT). By completing Table Q3(a) in your answer script, name the four biasing and modes of the operation of BJT. [4 marks]

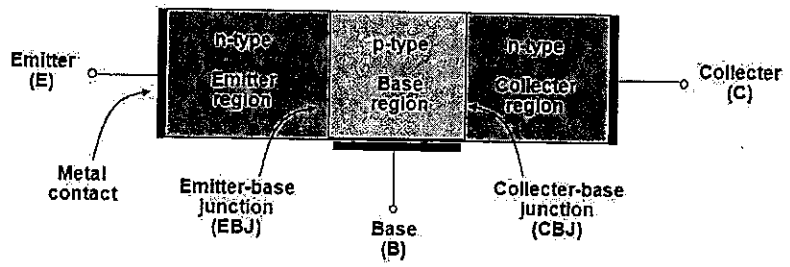

Figure Q3(a)

Table Q3(a)

Applied Voltages	Base-Emitter Junction	Base-Collector Junction	Mode of Operation
E < B < C	Forward-biased		
E < B > C	Forward-biased		
E > B < C	Reversed-biased		
E > B > C	Reversed-biased		

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(b) Name the three common configurations of the BJT circuits shown in Figure Q3(b) and briefly give reasons why they are categorised as such. [3 marks]

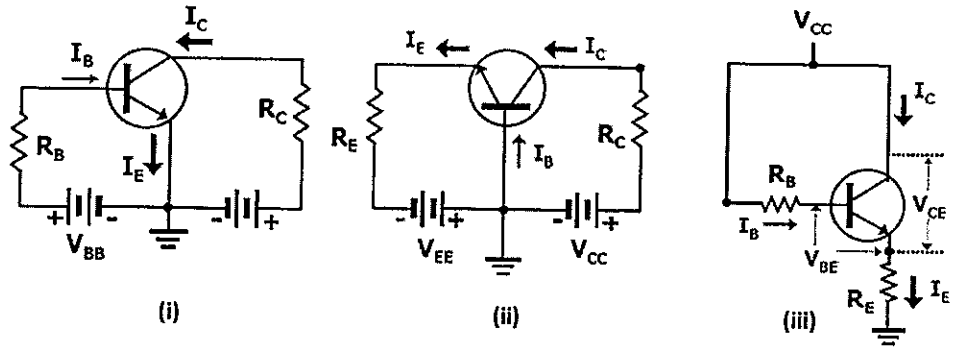

Figure Q3(b)

(c) Figure Q3(c) below shows a BJT circuit with given values of $V_{CC} = 20\text{V}$, $\beta = 100$, $R_C = 1\text{k}\Omega$ and $R_B = 100\text{k}\Omega$.

(i) Name the biasing configuration method of the circuit. [1 mark]

(ii) Determine the operating point values of $I_{C(Q)}$ and $V_{CE(Q)}$ of the transistor circuit. [8 marks]

(iii) Determine $I_{C(SAT)}$ and $V_{CE(OFF)}$. [2 marks]

(iv) Draw the DC load line, label and show the values of $I_{C(Q)}$, $V_{CE(Q)}$, $I_{C(SAT)}$ and $V_{CE(OFF)}$. [4 marks]

(v) Calculate the Stability Factor of the BJT circuit. [3 marks]

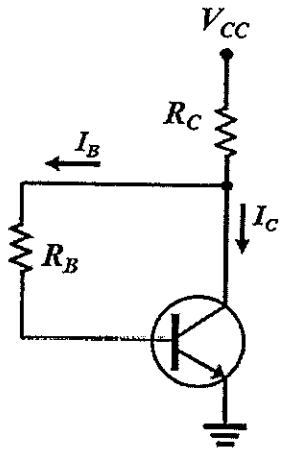

Figure Q3(c)

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QUESTION 4

(a) Figure Q4(a) shows a two-port circuit, which is connected to a signal source, v_s and a source resistance, R_S. The output of the circuit is connected to a load, R_L.

(i) Draw the *z-parameter* equivalent circuit of the two-port system. [3 marks]

(ii) If v_s = 10mV$_{rms}$, R_s = 200Ω and v_{in} = 5mV$_{rms}$, calculate the internal impedance Z_{in} of the two-port circuit. [3 marks]

(iii) If the no-load voltage gain Av_{NL} = 100, the load resistance R_L = 2kΩ and the output voltage v_o = 150mV$_{rms}$, calculate the output impedance Z_{out} of the two-port circuit. [4 marks]

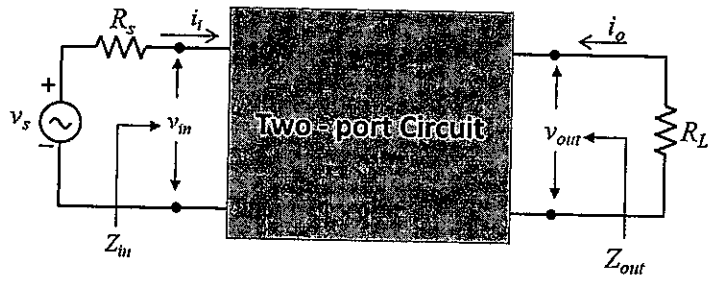

Figure Q4(a): A Two-Port Circuit

(b) Figure Q4(b) is a single stage Common Emitter BJT amplifier circuit. Draw the *h-parameter* model of the small signal equivalent circuit of the amplifier by showing all external and parametric components of the transistor. Include i_b, i_c and v_{be} in the drawing. [4 marks]

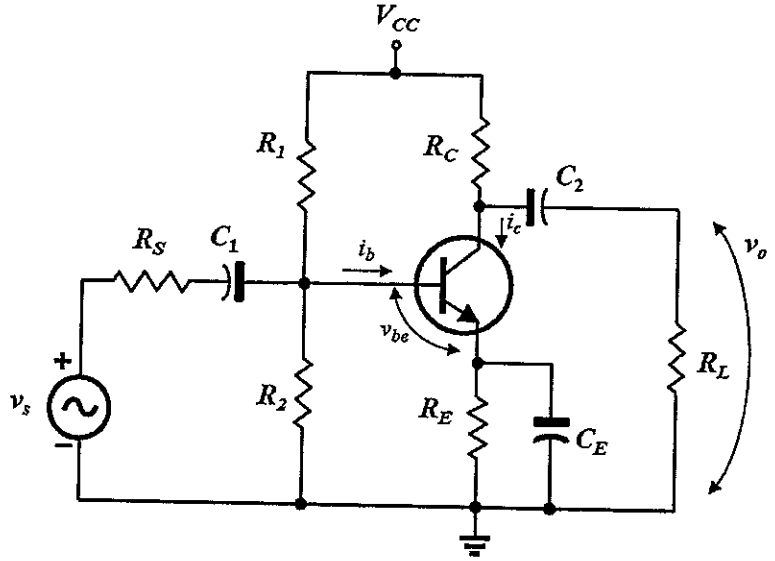

Figure Q4(b): A Common Emitter BJT Amplifier

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(c) Figure Q4(c) shows a BJT transistor amplifier circuit with $\beta = 150$.

(i) Draw the DC equivalent circuit of the amplifier. [2 marks]

(ii) By approximation method, determine the DC voltage V_B and hence calculate V_E (i.e. the voltage across emitter resistance, R_E). [3 marks]

(iii) Determine the emitter current I_E, the internal emitter resistance r_e of the BJT, and hence the value of βr_e. [3 marks]

(iv) If the output resistance of the small signal equivalent circuit, $r_o = \infty$, draw the r_e model of the amplifier. [3 marks]

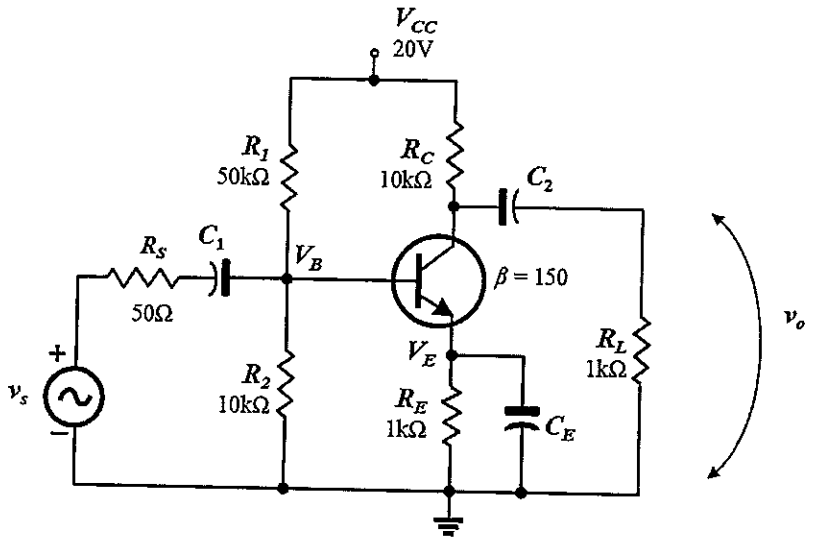

Figure Q4(c)

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Appendix

1. Charge of electron, $q = 1.6 \times 10^{-19}$ coulomb
2. Mass of electron, $m = 9.11 \times 10^{-31}$ kg
3. Holes and electrons in pure semiconductor, $p = n = n_i$
4. Law of Mass-action, $np = n_i^2$
5. Law of Electrical Neutrality, $\left(N_D^+ + p\right) = \left(N_A^- + n\right)$

   When all imprurities are ionised, $\left(N_D + p\right) = \left(N_A + n\right)$
6. In *n-type* semiconductor, $n_n \approx N_D$. In *p-type* semiconductor, $p_p \approx N_A$
7. Drift current density, $J_{drift} = J_n + J_p = \left(n\mu_n + p\mu_p\right)qE = \sigma E$

   for intrinsic semiconductor, $J_{drift(i)} = J_{n_{(i)}} + J_{p_{(i)}} = \left(\mu_n + \mu_p\right)n_i qE = \sigma E$
8. Characteristics of common semiconductors

Semiconductor	Intrinsic carriers/cm^3	μ_n (cm^2/V-s)	μ_p (cm^2/V-s)
GaAs	1.7×10^6	8500	400
Si	1.5×10^{10}	1350	410
Ge	2.5×10^{13}	3800	1800

9. Shockley diode equation, $i = I_o\left(e^{\left(\frac{V}{\eta V_T}\right)} - 1\right)$ where $V_T = \frac{kT}{q} = 26\text{mV}$
10. Form factor of rectifier, $FF = \frac{V_{o(rms)}}{V_{o(av)}}$
11. Ripple factor of rectifier, $\gamma = \sqrt{\left(\frac{V_{o(rms)}}{V_{o(av)}}\right)^2 - 1} = \sqrt{FF^2 - 1}$
12. RMS output voltage of half-wave rectifier, $V_{o(rms)} = \frac{V_{o(p)}}{2}$
13. RMS output voltage of full-wave rectifier, $V_{o(rms)} = \frac{V_{o(p)}}{\sqrt{2}}$
14. Average output voltage of half-wave rectifier, $V_{o(av)} = V_{o(dc)} = \frac{V_{o(p)}}{\pi}$
15. Average output voltage of full-wave rectifier, $V_{o(av)} = V_{o(dc)} = \frac{2V_{o(p)}}{\pi}$
16. Average output current of full-wave rectifier, $I_{o(av)} = I_{o(dc)} = \frac{2I_{o(p)}}{\pi} = \frac{2V_{o(p)}}{\pi R_L}$

17. Power dissipated at the load, $P_{(dc)} = I_{dc}^2 R_L$ and $P_{(rms)} = I_{rms}^2 R_L$

18. RMS output current of full-wave rectifier, $I_{o(rms)} = \dfrac{V_{o(rms)}}{R_L}$

19. Efficiency, $\eta_{\max} = \dfrac{P_{dc}}{R_{rms}}$

20. Internal emitter resistance of BJT, $r_e = \dfrac{V_T}{I_E} = \dfrac{26\text{mV}}{I_E}$